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Metals and Ceramics
Comparisons and Contrasts
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October, 1960

SCIENCE & TECHNOLOGY

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METALS REVIEW

The News Digest Magazine

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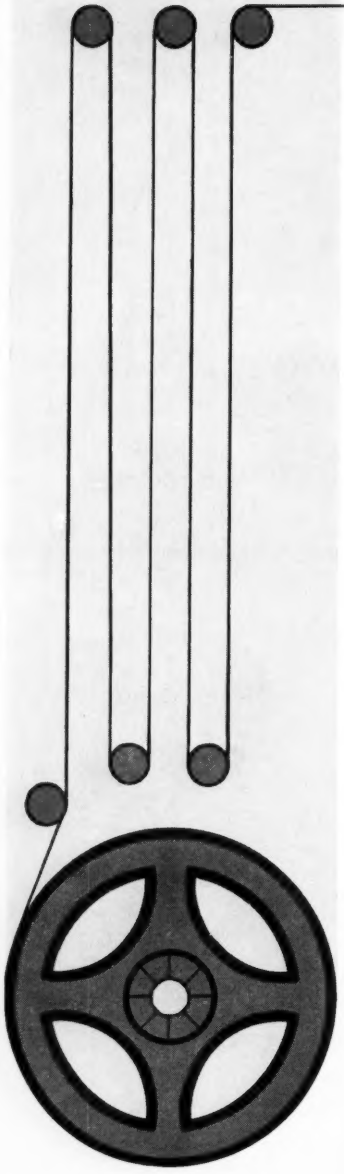

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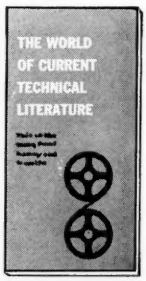

October, 1960 Vol. XXXIII, No. 10

METALS REVIEW

The News Digest Magazine

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Properties, Structures and Characteristics of Metals and Ceramics

by Lawrence H. Van Vlack*

Metals and ceramics have definite similarities. They also have definite differences. Although many metallurgists have not studied ceramics, it is possible for them to understand ceramics readily by making certain comparisons and contrasts between metallic and ceramic materials. This procedure is followed below so that generalizations may be presented.

COMPONENTS

Metals

Metals consist of elements which have one to four valence electrons. These are not firmly associated with any one atom.

Examples:
Fe—iron
Cu—copper
Mn—manganese

Ceramics

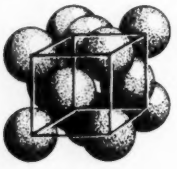
Ceramics consist of compounds of metallic elements and nonmetallic elements. The metallic elements lose their valence electrons and become positive ions. The nonmetallic elements receive extra electrons, or jointly share electrons.

Examples:
Fe_3O_4—iron oxide
$CuCl_2$—copper chloride
MnS—manganese sulphide

PHASES

Metal phases are relatively simple with all atoms similar in size. Since all atoms are similar in size, it is possible to coordinate each atom with a large number (8 to 12) of other immediately adjacent atoms.

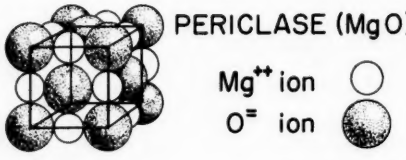
Examples: Body-centered cubic iron; face-centered cubic aluminum (see below).



FCC METAL

Ceramic phases are more complex because at least two different types of atoms, or ions, must be present. Smaller atoms cannot be coordinated with as many large atoms. The coordination number depends upon the size ratio. The positive and negative charges must balance.

Examples: Magnesium oxide (see below); magnesium orthosilicate (olivine).



PHASE NAME

It is convenient to assign names to phases. This is particularly true when more than one phase may exist for one composition.

Examples:
Ferrite—BCC iron
Austenite—FCC iron
Martensite—BCT iron

Names are also assigned to ceramic phases. With two or more types of atoms, more structural permutations and combinations are possible. Hence extensive use is made of names.

Examples:
Quartz—SiO_2
Fayalite—Fe_2SiO_4
Corundum—Al_2O_3

PHASE TRANSITONS

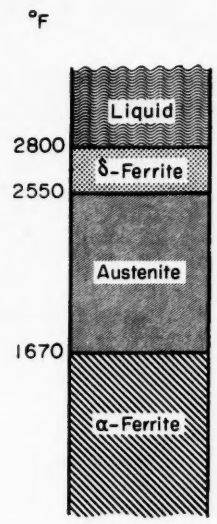
A change in temperature (or pressure) can change the crystal structure of many metals.

A change in temperature (or pressure) can produce crystal changes in ceramics. Transitions are more common in ceramics than in metals because there are a greater number of possible permutations of the elements which are present.

*Professor of Engineering Materials and Metallurgy, The University of Michigan, Ann Arbor.

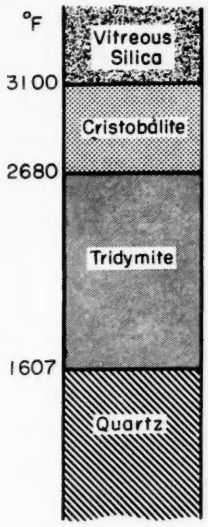
Examples:

IRON (Fe)



Examples:

SILICA (SiO_2)

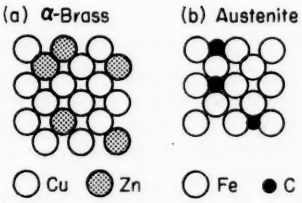


SOLID SOLUTION

(a) Within a metal structure, atoms may be replaced by similar atoms. Size is particularly important.

(b) Very small atoms may be located interstitially.

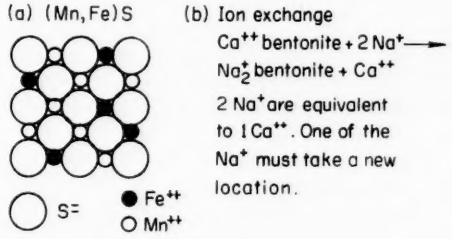
Examples:



(a) Ions may substitute for others of (1) similar size and (2) similar charge.

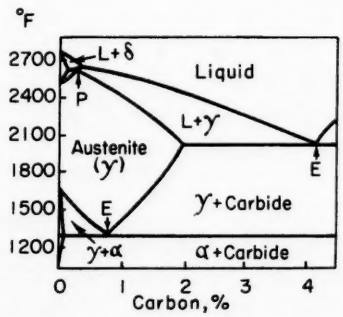
(b) Ion exchange is possible, particularly when there are large holes in the structure that can accommodate additional ions.

Examples:

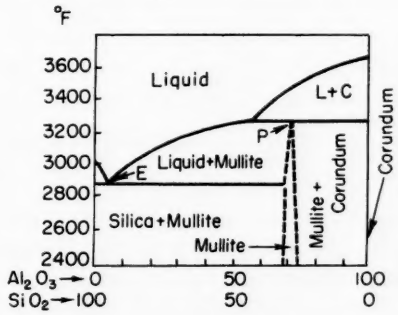

(a) (Mn, Fe)S
S=
Fe++
Mn++
(b) Ion exchange
Ca++ bentonite + 2 Na+ →
Na2+ bentonite + Ca++
2 Na+ are equivalent to 1 Ca++. One of the Na+ must take a new location.

PHASE DIAGRAMS

The prototype for metallurgical studies is the Fe-C system.



The prototype for refractory studies is the SiO_2-Al_2O_3 system.



REACTION RATES

Reactions are not immediate. Austenite in 1080 steel requires a few seconds to transform (a+C). (See sketch below).

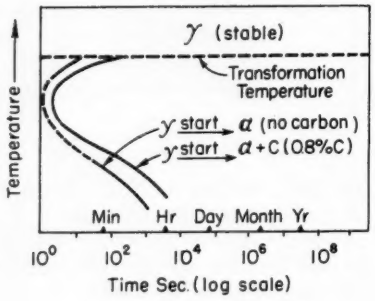
Reactions are faster at higher temperatures than at low temperatures *unless* a new phase must be nucleated near the equilibrium temperature.

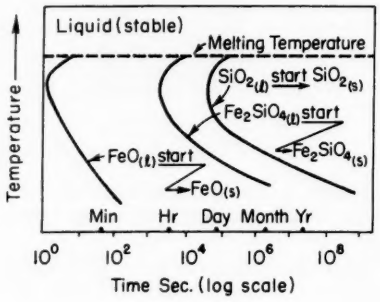
Reactions are faster when less diffusion is required (e.g., a 0.45% carbon steel transforms faster than a 0.80% carbon steel because less carbon must be relocated from the austenite to the cementite).

The reaction rates are slower in ceramics than in metals because (1) stronger bonds must be broken between individual atoms, and (2) a more complex structure requires more difficult rearrangements.

Reaction rates are faster at higher temperatures than at lower temperatures *unless* a new phase must be nucleated near the equilibrium temperature. (See sketch below).

Reactions are faster when smaller ions are involved (e.g., liquid FeO with Fe^{++} and $O^{=}$ crystallizes quickly on cooling and a glass does not form; fayalite [Fe_2SiO_4] with $SiO_4^{=}$ ions may not form from the liquid during rapid cooling; SiO_2 with an extended framework structure requires very long periods of time at high temperature for crystallization).





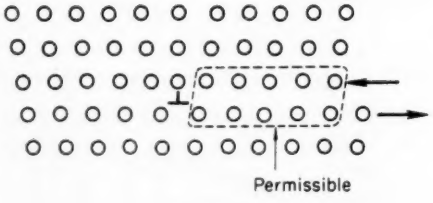
DEFORMATION

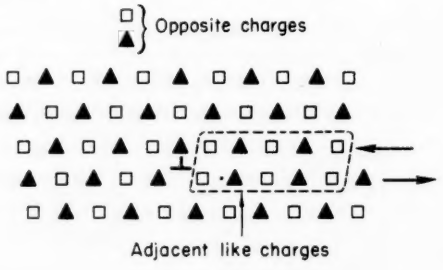
Plastic deformation requires slip of one crystal plane over another. This occurs through dislocations which produce stepwise shifts. (See sketch below). This occurs readily in highly symmetrical structures where all of the atoms are similar.

(and Intermetallic Compounds)

Slip of one plane over another is more difficult in ceramics because (1) more complicated, less symmetrical structures give fewer slip planes, and (2) a single stepwise shift may not be tolerated since repelling atoms (like-charged ions) may become adjacent. (See sketch below).

An ordered intermetallic phase (e.g., $CuAl_2$, B-brass, sigma Fe-Cr) also has these properties because a dislocation places like atoms together.





TOUGHNESS

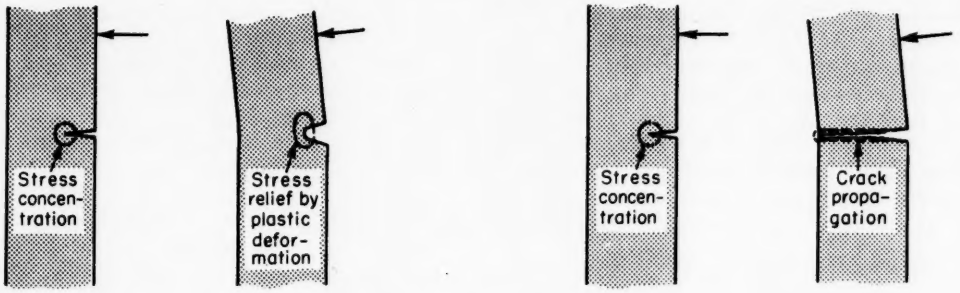
Most metals are ductile. A concentration of stresses produces a plastic adjustment and relief of the stresses. This adjustment consumes energy

(and Intermetallic Compounds)

A concentration of stresses cannot find relief through plastic deformation. Therefore, if the

and a large number of ft-lb. are required for fracture.

stress concentration exceeds the tensile strength a crack starts and accentuates the condition. Little energy is required to complete the fracture. Since toughness is measured by energy for fracture, these materials are brittle rather than tough.



STRENGTH AND HARDNESS

Ductile metals deform by shear. Since both tensile stresses and compressive stresses may be resolved into shear stresses, the mechanism of deformation is similar in each case. Therefore the tensile strength and compressive strength are comparable.

The bonds between atoms in ceramics are generally stronger than the bonds in metals. However, a concentration of tensile stresses cannot be relieved by plastic deformation. Therefore, the applied load for tensile failure may be low if geometric irregularities are present. The ceramic material may carry a large compressive load because shear failure will not occur.

MELTING TEMPERATURES

The melting temperature is an index of the strength of the bonds between the atoms. A strongly bonded atom must be given more thermal energy (e.g., higher temperature) before it may be dislodged from its location in the crystal.

Since the bonding energy in different metals varies widely, we find a wide variation in melting temperatures.

Examples:

Low bonding energy and low melting temperature	Mercury (−40°F.)
Intermediate	Aluminum (1220°F.)
Strong bonding energy and high melting temperature	Iron (2800°F.)

As with metals, the bonds between atoms in various ceramics are not identical. However, the average bond strengths are greater in ceramics than in metals. Expectedly the range of melting temperatures is higher. (See examples below).

A material with strong forces of attraction between the atoms will have high hardness as well as high melting point. We list materials such as silicon carbide, Al_2O_3, and silica as both refractories and abrasives.

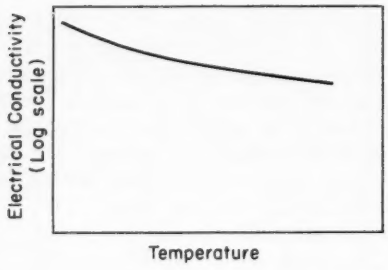
Examples:

Intermediate bonding energy and intermediate melting temperature	Cryolite (Na_3AlF_6) (1800°F.)
Strong bonding energy and high melting temperature	Silica (SiO_2) (3100°F.)
Very strong bonding energy and very high melting temperatures	Periclase (MgO) (5070°F.)

ELECTRICAL CONDUCTIVITY

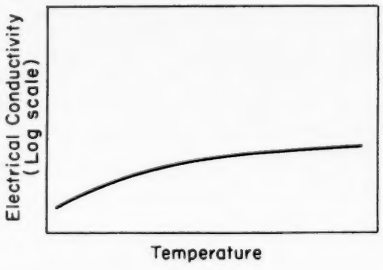
Metallic atoms have a limited number of valence electrons which are not firmly associated with any one atom. If a voltage difference is applied, the negative electrons can readily move to the positive electrode. This is electronic conduction.

The electrons move more readily in a perfect crystal structure. As the temperature of a metal is raised, and the atoms are thermally agitated to give a less perfect structure, the electron movement receives interference. Therefore, electrical conductivity is reduced at higher temperatures. (See sketch below). The most characteristic property of a metal is the decrease in conductivity at higher temperatures.



The electrons are strongly associated with the atoms in ceramic materials. Extremely high voltage differences must be applied before electronic conductivity may occur. Therefore, ceramic materials are insulators. A limited amount of conductivity may occur by ion movement. This is observed most readily in a liquid where the ions are free to migrate.

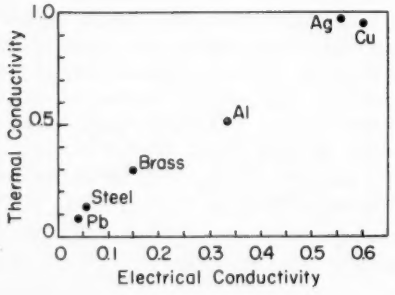
As the temperature is raised to high levels, more and more electrons are freed from their host atom or ion. Thus electronic conduction becomes possible at high temperatures. We find that ceramic materials characteristically possess an increased conductivity with increased temperatures. This variation of electronic conductivity with temperature is the most characteristic distinction between metals and nonmetals. (See sketch below).



THERMAL CONDUCTIVITY

Thermal energy can be transferred by agitation of adjacent atoms or by movement of electrons. The latter mechanism is significant in metals when the electrons are free to travel from atom to atom. Materials with high electrical conductivity generally have high thermal conductivity.

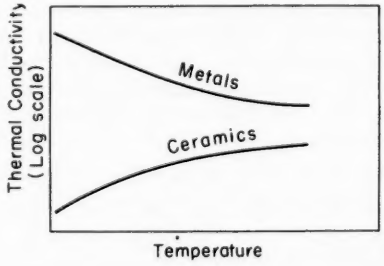
The thermal transfer through metals generally decreases as the temperature is increased.



Most ceramics, particularly at low temperatures, do have free electrons. Therefore, thermal energy must be transferred solely by the larger, slower vibrating atoms or ions.

As the temperature is increased, thermal energy transfer increases because (1) electrons become more available and (2) radiation transmission, which increases with the fourth power of temperature, becomes significant.

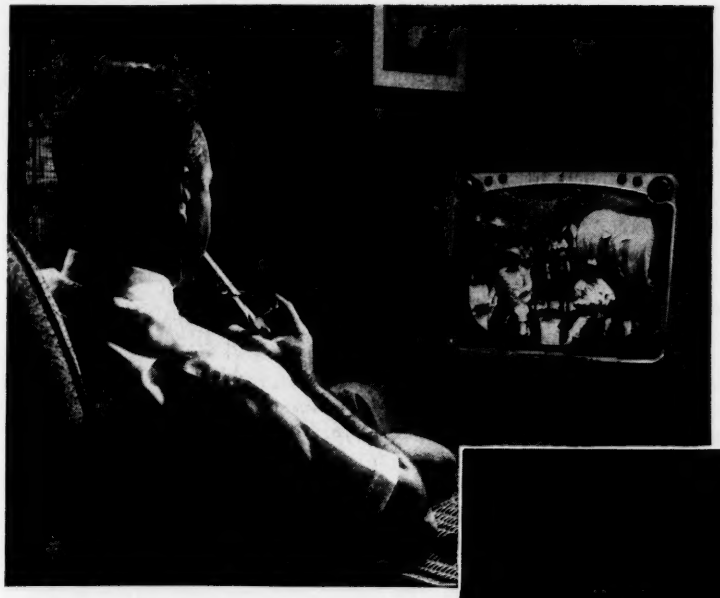
The thermal transfer through ceramics generally increases as the temperature is increased.



SUMMARY

Because metals and ceramics have similarities, they may be competitive materials for many applications. Because they have differences, there is frequently a preference for one over the other where specific properties are required. If lower melting temperatures (for casting), greater deformation (for shaping), or higher conductivities are required, ceramics are specified.

If the metallurgist understands the similarities and differences between various types of materials, he can meet his competition better and can reduce his design and production costs.



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Do you ever ask yourself "Do I know enough?" or "Would I be better off in the long run if I learned more?"

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Charts Progress in Nondestructive Testing

COMPARING PROGRESS IN ULTRASONIC flaw detection with the status of the art about five years ago, when pictorial images of gross defects were first possible, C. H. Hastings, group leader, nondestructive test development, materials department, Avco Research Center, pointed out to members of the Boston Chapter how porosity and inclusions as small as 1/32 in. can now be detected in thick electroformed copper heat sinks. Defects as small as 1/16 in. can be imaged on an ultrasonic flaw recorder with sufficient accuracy to permit direct size measurement. Special instrumentation using focussed ultrasonic beams was necessary to provide soundness evaluation and compliance with rigid thermodynamic requirements for the heat sink application.

To provide oxidation resistance for the copper, good aerodynamic smoothness and high reflectivity, the re-entry heat sink is coated with highly polished electrodeposited nickel. To assure adequate protective thickness after polishing, new electromagnetic (eddy current) techniques and equipment were developed. Employing a portable, transistorized and battery-powered instrument, nickel thickness from 1-12 mils can be gaged completely and rapidly to an accuracy of $\pm 10\%$.

A nylon cap on the hand-held probe prevents scratching the highly polished nickel surface. Attention to surface curvature, nickel plating variables and instrument stability are necessary to maintain accuracy.

The development of proven correlations by which the tensile strength of reinforced plastics and ceramics can be predicted by radiographic and ultrasonic nondestructive tests was described. These materials are frequently employed in metal-nonmetal sandwich or composite construction. The adhesive joints between layers of such structures can be evaluated for unbonded areas by a variety of pulsed ultrasonic techniques and frequently the unbonded interface specifically pinpointed so that repair work can be successfully accomplished. Since bond evaluation is dependent upon the uniformity of the materials involved, they must be evaluated ultrasonically, and sometimes radiographically, prior to the bonding operation.

Considerable success has been achieved recently in evaluating the adherence of flame-sprayed ceramic coatings on metallic substrates. Ultrasonic patterns and their qualitative interpretation were discussed and illustrated. *(Reported by D. A. Black).*

Use of Continuous Casting

THE USE OF CONTINUOUS casting methods has grown because greater tonnage of metal products is required by society, the shortcomings of non-continuous casting, and, once developed, operating costs are lower and products are possible which cannot be cast by other methods, according to Ralph Bailey, sales manager, continuous cast products, American Smelting and Refining Co., who presented a talk on "Continuous Casting of Copper-Base Alloys" at New Jersey.

The problems encountered in conventional casting techniques are indicated in part by the numerous reports on causes of porosity and other problems. These can frequently be overcome by continuous casting so that design engineers will no longer fall back on castings, with accompanying higher safety factors, only as a last resort.

Although continuous casting dates back to 1843, the first commercial casting operation started in 1930. This was followed by the introduction of direct chill techniques for aluminum and magnesium five and eight years later, respectively. The casting of copper and alloys also started at this time, using equipment obtained from Germany. Continuous casting was later applied to lead, tin, steel, stainless steel and other metals.

In continuous casting, five primary require-

(Continued on page 11)

Past Chairmen Meet

Past Chairmen Meeting at Worcester Included, Standing, From Left: W. J. Nartowt, L. G. Shaw, H. J. Elmendorf, J. C. Danec, W. J. Johnson, L. L. Krasnow and L. P. Tarasov. Seated are: C. M. Inman, W. Van N. Baker, W. C. Searle and A. L. Rustay.

ments must be met: ample supply of molten metal ranging from 100 to 70,000 lb. per hr.; mold open at both ends; suitable means of rapid heat withdrawal; accurately controlled metal withdrawal; and a moving cut-off.

Mr. Bailey covered casting at ASARCO where operations have progressed from the introduction of equipment for 3-in. billets in 1937 to processing of rods, tubes and shapes up to 9 in. in diameter in 1948, at speeds up to 1000 lb. per hr. In 1958, the casting of copper cake was introduced.

After the talk a film strip on continuous casting, melt to finished product, was presented. Continuous casting will not completely replace other casting methods but has become a good competitor by providing a product with no shrinkage, little gas and dirt and high physical properties. *(Reported by R. E. Liebendorfer).*

Ductile, High-Temperature Brazing Alloys

IN THE 18TH CENTURY aluminum was rated more precious than gold and silver. Modern reduction methods have reduced aluminum to a common metal but, due to their rarity, gold and silver still remain in their original classification, according to D. C. Herrschaft, Handy & Harman, who gave a talk entitled "Finding Tomorrow's Brazing Alloys Today" at Saginaw Valley.

The ease of application and moderate melting point spurred the use of silver brazing alloys during World War II. A significant development of the recent decade was the addition of 0.20% lithium to silver-copper alloys, such as sterling, which promoted self-fluxing properties. This alloy has found wide application in the brazing of stainless steel in honeycomb aircraft structures. The brazing temperature coincides with the solution heat treatment temperature of 17-7 pH stainless steel. The alloy is also immune to interfacial corrosion.

Nickel-base alloys have shown good oxidation resistance up to 1500°F. but several adverse effects are recognized. The Ni-Cr-Si-B alloys used by engine and parts manufacturers do not have the required ductility and also show considerable base metal penetration. The Mn-Ni type alloys were found difficult to use on honeycomb applications because of the necessary very dry brazing atmospheres, high brazing temperatures and the solution of the base metal.

The search for ductile, high-temperature alloys has focused attention to gold, palladium and platinum, which are ideally suited because of the ductile solid solutions formed with other high melting point metals. The phase diagrams of silver-gold, copper-gold and the ternary copper-gold-silver systems were described and illustrated with slides. A gold-nickel composition has excellent free-flowing properties and has been applied to the brazing of stainless steel and Inconel. Jet engine manifolds which operate continually at 1200°F. are joined by this alloy. This binary alloy can dissolve some chromium from stainless steel base metals to form a ternary Au-Ni-Cr alloy. Au-Ni-Cr and Pd-Ni-Cr systems show excellent oxidation resistance, high strength and a minimum of base metal solution.

Other possibilities for ductile high-temperature brazing alloys are the Pd-Ag, Pd-Au, Au-Pd-Ag, Pd-Cu, Pd-Ag-Cu and Au-Cu-Ni systems. If still higher melting points are required, platinum systems may be considered. Pt-Ni and Pt-Cu diagrams show higher melting points than the corresponding binary alloys with palladium. Finally, the platinum-iridium system shows compositions with a temperature range from 3200-4400°F. Workable alloys are presently limited to 20% iridium because of the extremely high annealing temperatures required for processing.

It is apparent that many compositions with flow points ranging from that of silver brazing alloys to above the platinum range could be produced and some are already in use. However, present brazing furnace muffles limit the temperatures to 2250°F. Industry must await better furnaces before wide acceptance of tomorrow's brazing alloys can be achieved. *(Reported by Homer D. Boggs).*

Chapter Briefs

A seminar sponsored by the **Hartford Chapter** covered The Physical Nature of Metal Fracture, Catastrophic Fracture, Fatigue Fractures and High-Temperature Fracture. Speakers were J. J. Gilman, metallurgy and ceramics research department, General Electric Co., M. E. Shank, department of mechanical engineering, Massachusetts Institute of Technology, J. A. Bennett, mechanical metallurgy section, National Bureau of Standards, and N. J. Grant, department of metallurgy, Massachusetts Institute of Technology.

Silicon as an alloying element is often neglected and yet it is known to have a high hardenability factor without decreasing the M_s temperature, according to Gordon E. Willey, vice-president in charge of sales, Electro Metallurgical Co., who spoke on "The Application of Nonferrous Metals in the Iron and Steel Industry" at **Ottawa Valley.** The elimination of quench cracking by replacing some of the alloying elements with silicon was cited as an example.

The Metals Handbook . . . an A.S.M. Team Achievement

WHILE 25,000 MEMBERS AND FRIENDS of American Society for Metals are participating in the 1960 Philadelphia Metal Show, a most significant event will be taking place hundreds of miles away in Skokie, Ill. Tuesday, Oct. 18, is the scheduled date for the presses to start delivering sheets of the new volume of the A.S.M. Metals Handbook.

In fact, advance pages from this volume, on "Properties and Selection of Metals", will be on display at the Metal Show so members can have a preview of the myriad items of new and useful engineering information available to them in a short time. All of the 32,000 members of the Society should have received their copies by the first of the year. This allows for printing, binding and mailing time.

Members of record as of distribution date will receive the new volume at no charge. New members entering the Society after that time will have the opportunity to purchase the book at a nominal $10, one third that of the nonmember price of $30. Members will keep their copies of the 1948 edition and its supplements.

Years in planning and preparation, this is without doubt the most monumental work of its type ever compiled anywhere in the world of metals. It is the first of several projected volumes in the new eighth edition. For comparison, its more than 1200 pages of technical information, documented and substantiated by actual working experiences in hundreds of metalworking plants, replace only about 350 pages of the last edition. A.S.M. is calling it the most complete and authoritative source book on properties and selection of metals ever assembled—and it is.

The Metals Handbook ranks with A.S.M. Chapter meetings as an example of members giving of their knowledge and experience to help other members and the industry in which they share a common enthusiasm. About 1200 men were directly involved in the new work, including 86 different author committees and many individual contributors. Most of these are members of A.S.M. Hundreds of committee meetings, tens of thousands of hours are behind the new Metals Handbook. When members re-

The Metals Handbook Committee Met at A.S.M. Headquarters to Plan Vol. II. Standing, from left, are: Taylor Lyman, editor; Ralph Leiter, Budd Co., vice-chairman; N. E. Promisel, Bureau of Aeronautics, chairman; Carl Samans, Standard Oil of Indiana, A.S.M. trustee; W. A. Pennington, University of Maryland, A.S.M. vice-president; Walter Crafts, Union Carbide Metals, A.S.M. president; and Allan Ray Putnam, A.S.M. managing director. Seated, in background; Paul Farrin, Hartford Machine Screw; William Burch, Bell Aircraft; Richard Doughton, Jones & Laughlin Steel; Al Hartley, Cincinnati Milling Machine; Dale Wright, Caterpillar Tractor; and Walter Dean, Alcoa. Seated, front: Claude Leland, General Motors; Roy McCauley, Ohio State University; Peter Payson, Crucible Steel; Elton Saples, Hevi-Duty Electric; George Dolch, Thompson Ramo Wooldridge; Stuart Fletcher, Latrobe Steel; Henry Zurburg, Chrysler; and Al Lloyd, A.S.M. controller.

ceive their copies, they can well imagine that behind every one of the book's 1200 pages is one man, one expert in some important phase of metals engineering, who has attended meetings, contributed ideas and compiled information.

And after the meetings are held, after the subjects are chosen, after the drafts are written, they must be assembled, reviewed by the committees, revised and edited. That's where the Metals Handbook department at Metals Park comes in: Taylor Lyman, the editor, and his staff—Howard E. Boyer, Joseph E. Foster, Paul M. Unterweiser, James P. Hontas and Helen L. Lawton, each an expert in some phase of technical publishing. Close cooperation of the Metals Handbook committees and staff have made this a real A.S.M. team achievement, and one from which members will benefit for years to come.

This is the kind of metalworking reference book for which, literally, no comparison exists. It contains more than triple the amount of usable information on properties and selection of metals, as contrasted with the last edition, and exhibits a significant increase in the number of alloys treated.

Now engineers will be able to approach a problem of selection from either of two sides. Tabular and graphical data are given, alloy for alloy. In addition, applications are discussed by categories from the standpoint of alloy selection for specific uses.

Major sections of the book deal with carbon and low-alloy steels, stainless steels, heat resisting alloys, tool materials, electrical and magnetic material, nonferrous metals and various special-purpose materials. This basic volume in the eighth edition is designed for those who need an authoritative reference book on engineering aspects of metals to answer on-the-job questions on properties and selection.

Metals Terminology

As a regular feature of *Metals Review*, there will appear each month selected definitions of terms used by metallurgists and engineers in the metalworking industries. These will be selected from the more than 3000 definitions to be found in the new "Metals Handbook" to be distributed in November and December of this year.

More than 140 men from all segments of the metalworking industry participated in compiling and developing these definitions. Ten separate committees were formed to carry on this activity under the chairmanship of A.S.M. president-elect William A. Pennington, professor of metallurgy at the University of Maryland. Four technical societies, including A.S.M. were represented on the committee on heat treatment terms. They are: A.F.S., A.S.T.M. and S.A.E.

BRAZING—Joining metals by flowing a thin layer, capillary thickness, of nonferrous filler metal into the space between them. Bonding results from the intimate contact produced by the dissolution of a small amount of base metal in the molten filler metal, without fusion of the base metal. Sometimes the filler metal is put in place as a thin solid sheet or as a clad layer and the composite is heated as in furnace brazing. The term brazing is used where the temperature exceeds some arbitrary value, such as 800°F.; the term soldering is used for temperatures lower than the arbitrary value.

BRINELL HARDNESS TEST—A test for determining the hardness of a material by forcing a hard steel or carbide ball of specified diameter into it under a specified load. The result is expressed as the Brinell hardness number, which is the value obtained by dividing the applied load in kilograms by the surface area of the resulting impression in square millimeters.

CONSTITUTION DIAGRAM—A graphical representation of the temperature and composition limits of phase fields in an alloy system as they actually exist under the specific conditions of heating or cooling (synonymous with "phase diagram"). A constitution diagram may be an equilibrium diagram, an approximation to an equilibrium diagram or a representation of metastable conditions or phases. Compares with equilibrium diagram.

COVERED ELECTRODE—A filler-metal electrode, used in arc welding, consisting of a metal core wire with a relatively thick covering which provides protection for the molten metal from the atmosphere, improves the properties of the weld metal and stabilizes the arc. The covering is usually mineral or metal powders mixed with cellulose or other binder.

CRITICAL POINT—(1) The temperature or pressure at which a change in crystal structure, phase or physical properties occurs. Same as transformation temperature. (2) In an equilibrium diagram, that specific value of composition, temperature and pressure, or combinations thereof, at which the phases of a heterogeneous system are in equilibrium.

STEEL—An iron-base alloy, malleable in some temperature range as initially cast, containing manganese, usually carbon, and often other alloying elements. In carbon steel and low-alloy steel, the maximum carbon is about 2.0%; in high-alloy steel, about 2.5%. The dividing line between low-alloy and high-alloy steels is generally regarded as being at about 5% metallic alloying elements.

Steel is to be differentiated from two general classes of "irons": the cast irons, on the high-carbon side, and the relatively pure irons, such as ingot iron, carbonyl iron and electrolytic iron, on the low-carbon side. In some steels containing extremely low carbon, the manganese content is the principal differentiating factor, steel usually containing at least 0.25%; ingot iron contains considerably less.

For Distinguished Service

Sauveur Achievement Award

Bruce Chalmers, Harvard University professor, received the Albert Sauveur Achievement Award of the American Society for Metals during the A.S.M.'s Annual Awards Luncheon at Philadelphia Trade and Convention Center.

The Sauveur Award is conferred for pioneering achievement effecting basic advance in metallurgical knowledge. Dr. Sauveur himself was the first recipient of the award, established in 1934. A pioneering metallographist, he produced the first photomicrographs of steel made in the United States.

Dr. Chalmers received his M.S., Ph.D. and D.Sc. degrees at the University of London, England, in physics. From 1932 to 1938 he was a lecturer in physics and mathematics there, after which he served with the Tin Research Institute, Ministry of Supply and Royal Aircraft Establishment.

From 1946 to 1948 he was head of the metallurgy division at the Atomic Energy Research Establishment, after which he went to the University of Toronto, Canada, as professor of physical metallurgy. In 1953 he became Gordon McKay professor of metallurgy at Harvard.

Howe Medal

A Dow Chemical Co. research engineer, John B. Clark, and a University of Florida professor of metallurgy, Frederick N. Rhines, shared the A.S.M.'s oldest honor, the Henry Marion Howe Medal, awarded during the Society's Annual Awards Luncheon Oct. 18.

The A.S.M.'s Howe Medal was established in 1922 to honor authors of the most outstanding Metal Congress technical paper and is nearly as old as the Society itself.

A native of Canada, Dr. Clark received his undergraduate degree in metallurgical engineering at the University of Toronto in 1948. He earned his master's and doctorate at Carnegie Institute of Technology in 1951 and 1953. As research engineer at Dow he carries on basic studies of phase equilibria, age hardening mechanisms and freezing processes of magnesium alloys.

Dr. Rhines, before assuming his present position as head of the metallurgical research laboratory and research professor of metallurgy at the University of Florida, served as professor of light metals and staff member of the Metals Research Laboratory at Carnegie Tech. It was there that he collaborated with Dr. Clark in authoring the 1960 Howe Medal paper. Dr. Rhines also won the Howe Medal in 1957.

After undergraduate work at the University of Michigan, from which he received his B S. in chemistry in 1929, Dr. Rhines earned his Ph.D. in metallurgy at Yale in 1933. He also received a certificate for a summer's work at the University of Berlin in 1932. He has authored some 60 publications appearing in technical journals and a book, "Phase Diagrams in Metallurgy".

A.S.M. Gold Medal

A Dayton engineer, John B. Johnson, became the 14th Gold Medalist of the American Society for Metals at the Society's Annual Dinner in Philadelphia.

The A.S.M. Gold Medal was established in 1943 to recognize outstanding metallurgical knowledge and great versatility in application of science to metalworking, as well as exceptional ability in diagnosis and solution of diversified metallurgical problems.

Dr. Johnson, considered one of the nation's leading experts on light metals, is now a consultant in his field. He retired as technical director of the Aeronautical Research Laboratory, U.S. Air Service, Wright-Patterson Air Force Base, Dayton, Ohio, in 1958, after a highly distinguished 42-year career with that organization (See *Metals Review*, p. 4, September 1958).

Advancement of Research

Elmer W. Engstrom, senior executive vice-president, Radio Corp. of America, received the American Society for Metals' Medal for the Advancement of Research on Thursday, Oct. 20, during the Society's Annual Dinner in Philadelphia.

Established in 1943 for pre-eminent metalworking executives, the Research Medal honors one who consistently has sponsored metallurgical research and development, and through foresight and influence has helped substantially to improve

technology in metalworking's materials and processes.

Dr. Engstrom is responsible for RCA Laboratories, Defense Electronic Products, Astro-Electronic Products, Engineering Services and Manufacturing Services staff activities. He joined RCA in 1930 as division engineer for RCA Manufacturing Co. at Camden, N.J.

He participated in early evaluation of television and was instrumental in development of operational black-and-white television. Then he and his associates conducted research which resulted in development of the RCA compatible color television system.

Dr. Engstrom became director of general research in 1942; director of general research of RCA Laboratories in 1943; vice-president—research of RCA Laboratories Division in 1945; vice-president in charge of the division in 1951; executive vice-president of the division in January, 1954; executive vice-president, research and engineering RCA, in June 1954; and senior executive vice-president of the corporation in 1955.

During World War II he was responsible for research in radar, radio, airborne television, electronics and acoustics. He received an honorary Ph.D. degree in 1949 from New York University. Among his many honors is the Christopher Columbus International Prize in Communications, which he was awarded in 1959 with David Sarnoff, RCA chairman of the board and V. K. Zworykin, RCA honorary vice-president, for "outstanding leadership in the development and introduction of television".

He is chairman of the Research and Engineering Advisory Panel on Electronics and a member of the Defense Science Board, Office of the Secretary of Defense, along with membership in a number of technical societies and committees.

Albert Easton White Award

Champion H. Mathewson, professor emeritus of metallurgy and metallography at Yale University, received the first of the American Society for Metals' newly established Albert Easton White Award on Thursday, Oct. 20, during the Society's Annual Dinner.

Dr. White was one of the five founders of American Society for Steel Treating, A.S.M. forerunner, and served as its first president. The award in his name will honor unusually long and distinguished service of a teacher of metallurgical engineering or related subjects.

Dr. Mathewson received the White Award for his "singular ability to inspire students and impart enthusiasm and understanding and for his metallurgical achievements". Since retirement from the Yale faculty in 1950 after 43 years of service he has operated as a consulting metallurgist from the University's Hammond Laboratory.

The Eisenman Award

Harry B. Knowlton, retired International Harvester Co. engineer, received the first American Society for Metals' William Hunt Eisenman Award for engineering achievement during the Annual Dinner at Philadelphia.

The Eisenman Award, established this year in name of the late A.S M. founder-member and 40-year national secretary, will honor outstanding contributions in practical application of metallurgy to materials production and engineering. The award will be conferred on one whose achievements have accomplished significant improvement in metallurgical processing.

Mr. Knowlton retired in December 1954, as chief engineer of International Harvester's materials engineering and engineering standards department. He had served 27 years with the Chicago-based firm. He has been engaged in metallurgical activities in automotive, tractor and ordnance fields for many years, and has authored a number of technical papers. His unusually active service with American Society for Metals includes a term as national trustee, 1952-1954.

C. H. Mathewson

H. B. Knowlton

F. N. Rhines

J. B. Clark

E. W. Engstrom

Phenomenon of Anisotropic Growth and Swelling

PROBLEMS OF DIMENSIONAL STABILITY of fissionable materials were reviewed by A. Boltax, Nuclear Metals Inc., at Eastern New York. Anisotropic growth and swelling behavior, with stress on the phenomenological aspects of the problem, were also reviewed.

Anisotropic growth of uranium and its alloys under irradiation is believed to be related to the displaced atoms produced by energetic neutrons and fission product atoms, and is principally observed in polycrystalline uranium with a preferred orientation and in uranium single crystals. The usual method of minimizing anisotropic growth as a source of dimensional instability is to produce a random texture in the uranium by a beta treatment. Unfortunately, the rather large grain size produced by beta treatment leads to the problem of surface "wrinkling" or "bumping", a phenomenon which exhibits itself by distortion of the surface of samples and is observed in coarse-grained uranium. The size of the bumps is related to the grain size. The explanation of "bumping" is based on the growth and contraction of each surface grain in the manner exhibited by a single crystal. Grains in the interior of the fuel material are restrained from changing their shape by neighboring grains. Anisotropic growth should not be confused with normal grain growth, in which case a grain grows by consuming neighboring grains. In anisotropic growth, an individual grain will grow and contract in particular crystallographic directions with no essential volume change.

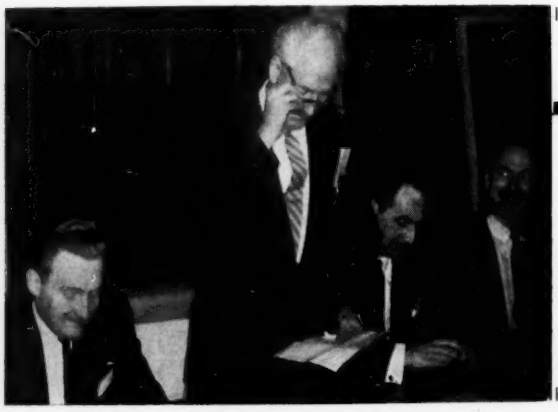
Two theories of anisotropic growth have been proposed. The first is based on anisotropic diffusion of lattice imperfections, the second involves nonreversible plastic deformation occurring during the thermal spikes which surround the region where the fission fragment and the lattice ions interact. At present, there are no direct experimental observations to support either theory.

Several reasons were given for alloying uranium besides the attainment of improved physical properties, including refinement of grain size, change in alpha-beta transformation temperature, effect of distribution of uranium as in the dispersion or precipitation-type alloy, stabilization of a high-temperature phase, such as the body-centered cubic gamma phase of uranium, and formation of low and high melting alloys.

Swelling refers to a volume instability which is related to the formation of gas pockets in uranium or uranium alloys due to the accumulation of the gaseous fission products. The inert gases, xenon and krypton, which make up approximately 10% of the fission products, are the major sources of swelling. After the fission event, xenon and krypton atoms are atomically dispersed in the fuel element.

If the fuel element temperature is sufficiently high, the gas atoms can diffuse, cluster and nucleate as gas bubbles. The available evidence indicates that xenon and krypton are present as charged ions in the uranium lattice and diffuse by the usual vacancy mechanism for substitutional solute elements. Evidence for bubbles in uranium have been reported by many investigators, even at low burnups and at temperatures as low as 200° C.

Some of the recent British experiments on swelling, carried out by alpha particle irradiation of various pure metals, were described. Practical methods of coping with the swelling problem in metal fuel elements include alloying and application of external pressure by cladding with high-strength materials. Dispersion-type fuel elements, where the fissionable phase is completely surrounded by nonfissionable matrix, have been designed to minimize the swelling in metallic fuel materials. Finally, ceramic fuel materials, such as uranium dioxide and uranium carbide, have demonstrated satisfactory resistance to swelling at high operating temperatures. *(Reported by Louis Ianniello.)*



"Experts" on Metallurgy

Toronto Versus Hamilton Experts in Metallurgy Discussd Their Specialties in a Recent Panel Meeting Held in Ontario. Shown, from left: J. S. Kirkaldy, McMaster University, R. C. Stewart, Vanadium-Alloys Steel Co., V. G. Behal, Dominion Foundries and Steel Ltd., and R. Smallman-Tew, Avro Aircraft Ltd.

CLEANING & FINISHING

Orbiting Echo Made of Thin Metallized Plastics

Most people who casually watch the Echo satellite during its rapid orbits about the earth would be amazed to know that the outer shell of the space traveler is only one-half of one thousandth of an inch thick (0.0005 in.) Echo only weighs 130 lb. although its inflated height is equivalent to a 10-story building and its area is 30,000 sq. ft.

The balloon-like sphere is made of Mylar, a clear polyester plastics film. The surface of the extremely thin plastics film is coated with aluminum, applied by metallizing under a high vacuum. The aluminum coating is estimated to be approximately seven-millionths of an inch thick.

Echo's basic function in space is to act as the first of a series of communications satellites from which radio and television signals can be bounced. The aluminum coating over the plastics film provides Echo with a high degree of radion wave reflectiveness.

The aluminum coating was applied by National Metallizing Division of Standard Packaging Corp.

Enameled Steel Used in Research House

Interest in a modified curtain wall system of construction for home construction is expected to result from the Ferro Research House recently opened near Cleveland. The home features the extensive use of porcelain enameled steel in side and end walls and in the roof.

Side and end walls are sandwich panels, 24-in. wide, with a 2-in. foamed polystyrene core faced on both sides with porcelain enameled steel. The roof panels are 24-ft. long porcelain enameled aluminum coated steel panels, insulated on the underside by 4 in. of glass fibre.

Considerable use is made of porcelain enameled steel panels in kitchen and bath wall surfaces, doors, carport and other outdoor surfaces, kitchen counter tops, drawers and a specially designed appliance wall.

Heavy Galvanized Music Wire Available

Development of a new galvanizing method by National Standard Co. has permitted that company to produce a coated music spring wire with 10 to 15 times the corrosion resistance of standard tinned music wire. The new wire eliminates the need of post plating and assures uniformly protected surfaces. The zinc coating is 3-7% by weight.

Electrostatic Spray Gun Shown

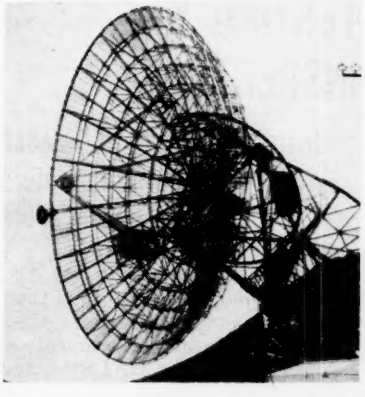
Revealed at the Metal Show for the first time was a portable electrostatic spray gun. The hand spraying system utilizes the basic principles of electrostatic spraying but pre-atomizes the paint particles by centrifugal action. The new system is said to permit "wrap-around" coverage with metallic as well as nonmetallic paints and extends the application of electrostatic methods to other types of paints without the need for special formulations. The equipment was exhibited by Ionic Electrostatic Corp., Garfield, N.J.

Welding & Joining

New Flux Promises to Speed Submarine Welding

A new welding flux that makes possible the use of submerged-arc welding in the construction of submarine hulls promises to lower production costs, according to welding technologists at Battelle Memorial Institute. The experimental flux resulted from an extensive program authorized by the U.S. Navy's Bureau of Ships to determine how submerged-arc welds on high-strength structural steel hull plates could be improved to meet Bureau requirements. Meanwhile, almost all welding of such steel has been done manually with coated electrodes to assure desired notch toughness.

High oxygen contents and numerous silicate inclusions in submerged arc welds on HY-80 structural steel prepared in shipyards pointed up



LISTEN TO ECHO—*Tracking the recently launched Echo satellite requires complicated, precision-built antennas such as this. The 200-ton steel antenna shown has an aluminum reflecting surface. Fabricated by Blaw-Knox Company, the antenna is operated by the staff of Jet propulsion Laboratory in a remote section of California.*

the need for a new flux. Reducing oxygen and the number and size of inclusions improved the welds, Battelle technologists observed. Studying a number of experimental fluxes, they developed one that gave excellent welds. This new flux is less acid than one now in use, because it contains relatively little silica and an exceptionally large amount of calcium oxide.

Using the new flux and commercial wire, joints have been welded with a yield strength of about 90,000 psi., ultimate strength of 100,000 psi., excellent tensile ductility and notch impact values of 30 ft-lb. at —100°F. Previously welds with comparable yield and ultimate strengths had values of 10 to 15 ft-lb. at —100°F. In addition to the decided improvement in low-temperature notch bar behavior, an equally striking improvement has been obtained in the notch bar behavior at room temperature.

New Bonding Technique Revealed

Aluminum balls are the key ingredients in a new joining method known as "ball-bonding" developed by Twin Coach Co. for use in bonding aircraft components. The process is said to be particularly efficient and economical in joining irregularly shaped parts.

Spotwelding Hardenable Steels

Precise information on spot welding of many hardenable steels which can be joined by this method is given in a brochure prepared by the Taylor Winfield Corp. Step-by-step instructions are given for set-up, welding and testing. Weld quality is classified and data charts summarize the welding schedules on various steels.

TESTING & INSPECTION

Instrument Permits Detailed Study of Low-Temperature Failure

Low-temperature studies of metals, particularly the pattern of their stretching and breaking, are aided materially by a new instrument developed by Arthur D. Little, Inc.

STEELMAKER LEARNS STEELMAKING—*Practice and theory in blast furnace operation have been brought together by John J. Caviness (left), blast furnace blower at Kaiser Steel Corp. Theory and principles were acquired through the M.E.I. course "Iron Blast Furnace Practices". Caviness is shown here receiving his M.E.I. certificate of completion from Supt. Robert B. Newmeyer of Kaiser steel. ". . . after 21 years working in the blast furnace department, your M.E.I. course on Blast Furnace Operations helped me more in my work than any book or paper I have read."*

First installation of the device—a special cryostat—has been made on existing tensile test equipment at the Watertown Arsenal.

It is important to have tensile test data in the temperature ranges such as are now being encountered in our satellite and missile programs, including the problems of fueling rockets with liquefied gases.

The tensile test cryostat has two basic elements: a cooling chamber and an automatic measuring device. Through the use of liquid nitrogen and liquid helium, the chamber can be refrigerated to —452.0°F. Two pairs of sliding calipers inside the chamber scan the specimen's dimensional deviations during stress applications. Measurements are relayed to a computer-recorder which plots a stress-strain curve.

In early tests, the instrument has been accurate to ± 0.001 in.

Electron Probe Microanalyzer

The key to unlocking the problem of better steels might be found in a new instrument just installed at the Graham Laboratory of Jones & Laughlin Steel Corp. The device, known as an electron probe microanalyzer, permits the study of extremely small areas in steel and steel products. Among other things, the microanalyzer makes possible the combined study of microstructure and chemical composition of steels. It can be used in development work as well as in quality control.

A major advantage of the microanalyzer is in its ability to determine the exact composition of a minute segment of steel in its natural or original place. It can detect the changes in chemical composition, from one microscopic grain to another, which might have occurred during solidification, processing and heat treatment.

The unit operates through use of a high-energy electron beam which excites X-ray emission from atoms within the region under examination. Crystal analyzers and Geiger counters measure the identifying X-radiation and determine the amounts of individual elements.

Some idea of the small area involved in these determinations can be gained from the fact that no difficulty would be encountered in carrying out an entire series of analytical tests on the broken end of a sewing needle.

X-Ray Unit Produces Bright Fluoroscopic Image

Interior flaws of a wide variety of metal products can be detected nondestructively with fluoroscopic Picker Industrial Image Amplifier, featured at the National Metal Exposition. The X-ray unit permits

continuous rapid inspection, partially because it produces an image for examination that is more than 1000 times as bright as that on a conventional fluoroscopic screen. Because of its brightness, the image can be viewed under normal room lighting, transmitted by television or recorded on photographic film.

Thermocouples Encased in Magnesium Oxide

Thermocouples likely to be subjected to service in applications involving gases, alcohols, oils, liquid metals, fatty acids, hydrogen peroxide, nuclear reactors and melt furnaces are now protected by encasing them in magnesium oxide. The thermocouple elements and wire are coated with magnesium oxide which is then processed into a chemically clean sheath. The thermocouples are produced by Wheelco Instruments Division, Barber-Colman Co., in a range of styles, sizes and lengths.

METALS

Precipitation Hardening Copper Alloy

A new bronze alloy now under production at American Brass Co. is of particular interest to the electronics industry because of its unusual combination of properties. The alloy, composed of copper, lead, nickel and phosphorus is said to offer high corrosion resistance, high tensile and yield strength, high electrical conductivity and is easily machined.

The alloy is precipitation hardening, a feature which is said to be responsible for its hardness and strength. Cold work, such as drawing or rolling, subsequent to the proper thermal treatment adds to the alloy's strength. A tensile strength of about 100,000 psi. can be obtained. The precipitation hardening quality is provided by nickel and phosphorus in the alloy. Lead provides the free machining property.

Suggested uses for this new alloy include electrical contacts, connectors, control elements for power tubes and structural elements now using copper. At present the leaded nickel copper is produced in round rods in sizes from 3/32 in. to 1¼ in. diameters.

150,000 PSI. Steel Without Heat Treatment

A new alloy steel bar that provides the user with a minimum tensile strength of 150,000 psi. without heat treatment has been announced by La Salle Steel Co. It is 4100 series steel with a minimum carbon of 0.40%.

In addition to its high strength, e.t.d. 150, as the steel is identified, has a guaranteed minimum hardness of 32 Rockwell C.

New Corrosion Theory Cited

Hydrogen, often blamed for the embrittlement of metals, is now being pointed out as the prime cause of corrosion in metals. This theory comes from investigators at the Westinghouse Electric Co. research laboratories.

It has been widely taught and accepted for many years that corrosion — at least a large share of it — resulted from an electrochemical action. A flow of current which exists between molecules of different electrical potential in the presence of moisture has long been considered the basic mechanism of corrosion.

In the explanation forwarded by Westinghouse, the hydrogen ions (atoms that have lost one electron) create minute pitholes in the metal. Then, the theory explains, oxygen from water enters through the pitholes and rusting begins.

Certain metals are more rust resistant than others, according to the theory, because they are less susceptible to pitting by hydrogen ions.

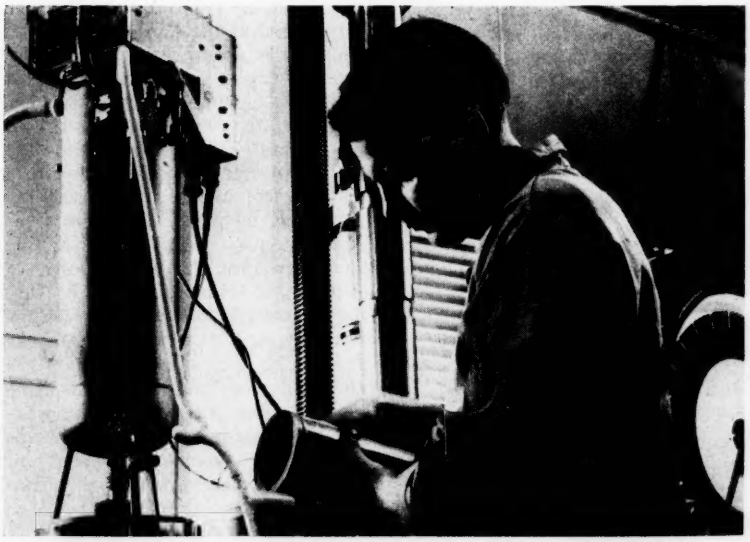
New Stainless Provides Hot Hardness

A share of the credit for making possible high speed landings of Boeing 720 and 707 jet airliners goes to a special grade of stainless steel. Developed by Latrobe Steel Co., the stainless is used in bearings and races of pneumatically controlled mechanisms which reverse the forward thrust of the aircraft engines.

During the high speed landings, the stainless is subjected to a maximum compressive stress of more than 600,000 psi. and temperature elevations in excess of 800° F.

The stainless is a modified 440 C which, by an increase in the molybdenum content, is provided with necessary hot hardness to enable the steel to withstand the extreme stresses at high heat levels.

Elevated temperature testing indicates the new stainless retains hardness of 3 to 5 points Rockwell C above that for 440° C stainless. Other high-temperature applications in turbines and jets are now being investigated.



TESTS AT LOW TEMPERATURES—*An engineer at Watertown Arsenal is filling the chamber of a special cryostat with liquid nitrogen. The instrument helps determine strengths of materials at temperatures as low as —452.0° F.*

Metal Strip Made From Powders

Improved reliability, increased life and better uniformity in electron tube parts is anticipated by Sylvania Electric Products, Inc., through a new use of powder metallurgy. The innovation is concerned with the cathode — the heart structure of electron tubes.

Sylvania has started to fabricate electron tube materials by compacting metal powders of closely controlled composition. This method replaces the earlier technique by which cathode materials were melted and cast from ingots. In the Sylvania process, high purity nickel or nickel with alloying powders are compacted, sintered and rolled into strips from which cathodes are formed.

A major advantage claimed for the new process is that cathodes are given more uniform electrical characteristics and improved high-temperature strength.

Similar methods are being used in the production of new base metals and alloys for study as potential cathode materials.

Uniform high strength is achieved through an elevated temperature drawing process. By the process, the steel bar is drawn at preselected temperatures considerably above room temperature, but below the lower critical temperature.

Prospective uses for the specially treated bar stock is in the manufacture of shafts, gears, pinions, fasteners, axles and other parts where heat treated alloy steels are now specified.

Palladium in Titanium Improves Corrosion Resistance

Recent tests have confirmed that a titanium-2% palladium alloy has excellent corrosion resistance. These tests have been conducted in reducing-type environments such as are encountered in a nuclear research laboratory and the plant of a chlorine chemical producer.

For comparative purposes, in one test samples of commercial titanium and the new alloy were suspended in boiling 5% sulfuric acid. The commercial titanium was removed after 85 hrs. because of excessive corrosion. Tests on the titanium-palladium alloy continued for 170 days and showed an extremely low corrosion rate.

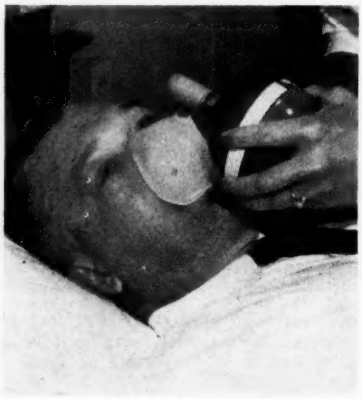
Metal Briefs

By means of a new process for producing spherical powders of metals and alloys, Linde Co. is now making available powders of copper, aluminum, nickel, 316 stainless steel, tungsten and Nichrome with particles ranging in size from 20 to 150 microns with uniformity rate of 98%.

Seven-inch wide coils of cold reduced steel strip from 0.060 to 0.0005 in. or less are being produced on a new 7½-in. Sendzimir mill at the Research Center of Republic Steel Corp. Originally the mill was used for rolling of ultra-high strength steels, but interesting results are being obtained in rolling carbon steel, silicon steel, titanium and many stainless grades.

The combination of a new series of heat treatable aluminum alloys and chromium plating process leads Kaiser Aluminum and Chemical Corp. to claim that light metal automobile bumpers can be made that will be priced competitively with those made of steel. Road tests are now being conducted with the aluminum bumpers.

STEEL SOLVES OXYGEN BOTTLE PROBLEM — *A one-hour supply of oxygen is contained in the round 32-oz. steel container shown here. Previously equipment for supplying a like amount of oxygen weighed as much as 125 lb. The startling weight saving resulted from use of a recently developed high strength steel and special hydrogen brazing techniques. The steel, a product of Great Lakes Steel, is a high strength, low alloy material with controlled additions of columbium.*



INDUSTRIAL HEATING

New Salt Bath Furnace Promises High Performance

A new concept in salt bath furnace design was revealed at the National Metal Exposition in Philadelphia by the Upton Electric Furnace Co. Highly effective use of convection currents created in the molten salt by heat from electric current permits, in one hour, the heating from room temperature to 1600°F. of 1200 lb. of steel. In the same period 800 lb. of steel can be heated to 2300°F.

Heating is achieved by passing an electric current through pairs of oppositely sloping passages or tunnels in the walls which separate the main portion of the salt bath from adjacent small wells where current is introduced by ordinary hanging electrodes.

Through the new design there is achieved a recirculation of salt from electrode well to main salt bath with the result that differences in salt bath temperature is slight. Too, the design permits a much greater supply of power to the bath.

Furnace Reduces Heating Time

A reduction in heating time of up to 85% is the promise of another new heating treating development introduced at the Metal Show. Also shown was a new automatic indexing box furnace using molybdenum heating elements. Both pieces of equipment were develped and shown by General Electric Co.

The automatic indexing box furnace is designed for high-temperature, low dewpoint operation without the use of an alloy muffle. Low dewpoint operation, down to —60°F., is achieved in part by furnace construction and the use of entrance and exit purge chambers to prevent atmosphere contamination and greatly reduce atmosphere consumption. Automatic timing increases gas flow in the purge chamber when a new load is inserted and prevents further tray movement until purging is completed.

Designed for used with hydrogen or disassociated ammonia atmosphere operation, the furnace shown will be used to bright process stainless steel.

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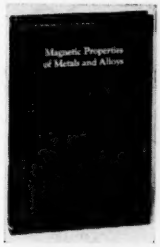

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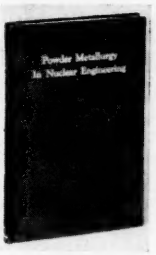

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(Continued on page 27)

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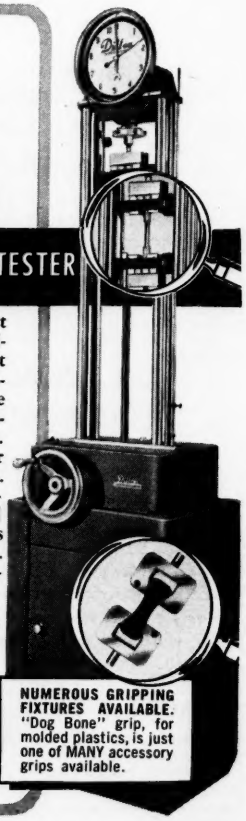

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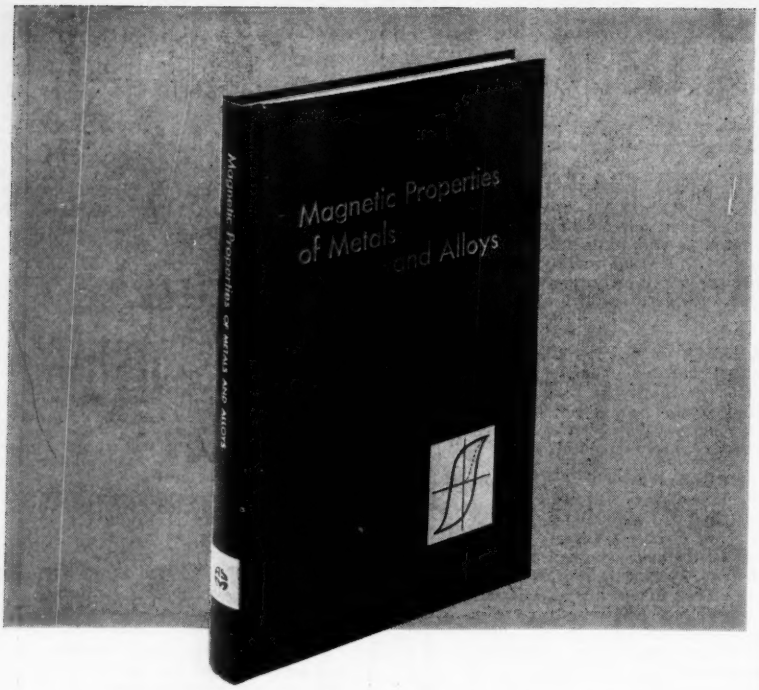

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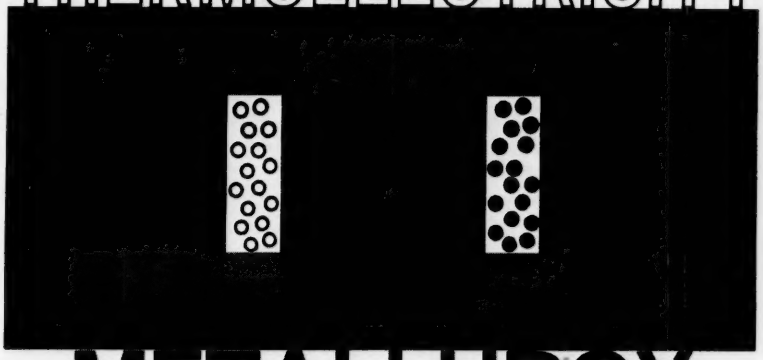

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The Beryllium Corporation
P.O. Box 1462, Reading, Penna.

Employment Service Bureau *(Continued from page 22)*

corporated. Send complete resume in confidence to principal. Box 10-35.

METALLURGICAL ENGINEER: Graduate. Experience in low-alloy and austenitic high-temperature alloys preferred, but will consider recent graduate. Assignment in process control laboratory of major automotive parts manufacturer. Work covers forging, cold forming, heat treating methods. $6500-$9600. Cleveland area. Box 10-40.

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RESEARCH METALLOGRAPHER: Fifteen years metallurgical laboratory background in ferrous and nonferrous testing and outstanding aptitude for high-grade photomicrography, including color. Will relocate to take advantage of opportunity for optimum application of ability. Resume of education and industrial experience furnished on request. Box 10-45.

ENGINEER-MANAGER: B.Met.E., registered professional engineer. Eighteen years successful experience in engine component and nuclear reactor fields. Heavy nonferrous process and electrochemical background, research, development, design and production. Desires responsible position in technical management with progressive manufacturing organization. Eastern or Midwestern location preferred. Age 41. Resume and references on request. Box 10-50.

METALLURGIST: B.S., age 29, married. Presently chief metallurgist and laboratory supervisor for large manufacturing plant. Experienced in heat treating, forging, welding, machining, gray and ductile iron castings. Desires applied research or development work with small progressive company or independent research laboratory. Will relocate anywhere in the U.S. or overseas. Box 10-55.

METALLURGIST ENGINEER: B.S., age 27, married, family. Experience includes ferrous and nonferrous metallography, failure analysis, machining problems, chemical analysis, heat treating, quality control and extensive report writing. Desires position in Chicago area. Box 10-65.

SALES EXECUTIVE: Twenty years experience selling and supervising sales of tool, die and stainless steel. Fifteen years in Midwest, past five years California, Arizona and New Mexico. Now located in Scottsdale, Ariz., and would like to represent reliable toolsteel company in Arizona and New Mexico. Married and free to travel. Resume on request. Box 10-60.

METALLURGIST: Young, agressive metallurgist with wide experience in research and development and pilot plant production of nuclear fuel alloys and other special metals, desires position with a future. B.S. plus five years experience in vacuum melting, powder metallurgy, roll bonding and handling of radioactive and toxic materials. Box 10-70.

METALLURGICAL ENGINEER: B.A.Sc., age 39, family. Wishes to return to the West. Ten years excellent experience in primary alumimum production including melting, refining, casting, project engineering and design, fabrication, metallurgical development and control. Proven administrative ability. Desires position in Pacific Northwest. Box 10-75.

METALLURGIST: M.S., two years production metallurgy, heat, corrosion and abrasion resistant alloys. Ten years project engineer and administrator applied metallurgy research. Excellent materials engineering background, high-temperature applications including specification preparations. Desires laboratory administrative position—executive classification, or, as an alternate, responsible technical services or customer contact position. Age 39. Box 10-80.

CHEMICAL METALLURGIST: Age 43. Diversified work in chemical and metallurgical engineering, four years in research and development of new nonferrous alloys. Desires responsible position in New York State. Box 10-85.

METALLURGICAL ENGINEER: B.S., age 35, married, one child. Five years gray iron foundry laboratory experience. Last three and one-half years production metallurgy, all phases plain carbon and alloy steel, heat treatment. Interested in Midwest location in either foundry or production metallurgy. Resume on request. Box 10-90.

METALLURGIST: M.S. in physical metallurgy. Ten years experience including eight years in refractory metals, with particular emphasis in molybdenum and tungsten. Experience includes development and original research resulting in publications. Desires career position, preferably in metallurgical supervision of research, development, etc. Box 10-95.

MANAGEMENT LEVEL METALLURGICAL ENGINEER: B.S., age 36, family, veteran. Eleven years diversified experience in production, development, laboratory and sales in ferrous and nonferrous fabrication, alloy application, furnance sales, metallography trouble-shooting, plant layout, commercial heat treat management. Alert to demands of industry, capable, decisive. Seeks challenging position in sales or management. Midwest preferred. Box 10-100.

CHIEF METALLUGIST: M.S. in industrial management. Age 38. Thorough production laboratory and production experience. Strong background in welding, thermit, nonferrous metals production. Familiar with pressure vessels, extrusion, forging, casting, plating, heat treating, radiography, quality control. Desires position as laboratory or process manager. Box 10-105.

MATERIALS ENGINEER—METALLURGIST: Age 47, M.S., family. Experience in polyurethane foams, printed circuits, potting, encapsulation, adhesives, ferrous and nonferrous alloys, metal finishing, titanium, beryllium honeycomb, electrochemistry, explosives, rockets, fuels, technical writing, materials and process specifications. Present salary $900 month. Preference: California, Arizona, New Mexico or Florida. Box 10-110.

SALES ENGINEER: Family man, age 31, aggressive type, desires position as technical representative. B.S. in business administration with the following professional experience: three years assistant chief metallurgist, diesel fuel injection equipment and electrical products; two years materials specification analyst with business machine manufacturer; two years in metallurgical quality control of aluminum foundry. Salary requirement $800 month. Box 10-115.

METALLURGICAL ENGINEER: B.S., age 36. Ten years diversified experience in missile, nuclear and jet engine industries. Knowledge of ferrous, nonferrous and high-temperature alloys. Desires responsible position in research and development or manufacturing. Will relocate. Box 10-120.

SENIOR METALLURGIST: Age 36, total 15 years in metals industry, including eight years of responsible charge. Experienced in quality control and trouble shooting of metal manufacturing problems, ferrous and nonferrous processes and practices. Seeking responsible position with growth possibilities; prefers Western United States. Present salary $11,-100. Resume on reqeust. Box 10-145.

METALLURGICAL ENGINEER: B.S. degree, with four years experience in research and development, including two years as foundry project engineer using high vacuum induction furnaces. Directed design and installation of equipment for fabrication of atomic reactor fuel elements. Desires work in production with possibility for advancement into management. Prefers West or South. Age 30. Box 10-150.

METALLURGIST: Graduate with 20 years professional metallurgical engineering experience encompassing research, development and manufacturing. Thoroughly experienced with the application, fabrication, etc., of cast and wrought ferrous and nonferrous materials, refractory metals, etc. Associated with major engineering organization in supervisory capacity. Desires association with growing organization in managerial position or position leading to high level of responsibility. Presently located on East Coast but will relocate. Box 10-155.

METALLURGICAL ENGINEER: M.S.E. degree, age 37. Over nine years diversified experience in alloy development and materials application for flight propulsion, automotive and electrical industries. Desires supervisory or other responsible career position. Resume on request. Box 10-170.

SENIOR RESEARCH METALLURGIST: Ph.D. degree in physical chemistry, with fourteen years experience in metal joining materials and methods. Established phase diagrams of ternary precious metal alloys. Various technical publications here and abroad. Desires responsible position in applied research. Location preferred: Chicago or Northeastern States. Box 10-175.

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